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(54) **Apparatus for inspecting printed matters.**

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Description

This invention relates to an apparatus for inspecting printed matter and, more particularly, to an apparatus for discriminating a replica of a printed matter, for instance a false or counterfeit bank note, from the original, i.e., the true or authentic bank note, by an optical method.

Up to date, printing techniques and copying techniques have been advanced outstandingly, and color copiers are available as commercial products. In these circumstances, it is liable that valuable securities such as bank notes and checks are deftly copied for improper use. Bank notes are manufactured by elaborate multi-color printing to prevent manufacture of counterfeit paper money. However, there are already cases where copies of bank notes are produced using multi-color printing processes or color copies, which copies cannot be discriminated from the originals by a mere visual inspection.

Prior art document US—A—4,204,765 discloses an apparatus for inspecting printed matter having an ink capable of reflecting electromagnetic waves outside the visible range. The apparatus comprises means for irradiating the printed matter with electromagnetic radiation of a predetermined wavelength range, means for forming an electric signal according to the energy distribution of electromagnetic waves reflected from said printed matter, means for inspecting the printed matter according to said electric signal, and a memory area for storing output signals from a photo-detector representing the levels of light at different wavelengths reflected from a print section of the printed matter. The function of the inspecting means is to compare the levels of the components of the signals stored in the memory area with reference values determined from a valid printed matter. The apparatus may also include comparators for comparing the levels of two different components stored in the memory area. The printed matter can include several print sections. The ink used for impressing the printed sections may be colored or an ink which is either absorptive or transparent with respect to infrared light.

An object of the invention is to provide a printed matter inspecting apparatus, which can readily and accurately discriminate a copy of a printed matter from the original even if it is difficult to discriminate the copy as such by a visual inspection.

According to the invention, the above object is attained by an apparatus for inspecting a printed matter comprising means for irradiating at least a section of the printed matter with electromagnetic radiation of a predetermined wavelength range, means for forming a plurality of electric signals representing the spectral energy distribution of the electromagnetic radiation reflected from the inspected printed matter, and inspecting means including a first memory for storing said plurality of electric signals and judging means for determining whether the inspected printed matter is an authentic one on the basis of the electric signals stored in said first memory, said apparatus being characterized in that said means for forming said plurality of electric signals includes a like plurality of photoelectric converters, and said inspecting means further includes a second memory in which a like plurality of reference data is stored, said plurality of reference data representing the spectral distribution of the reflectivity of authentic printed matter and having a reflectivity peak in a wavelength region in the visible range, higher reflectivities than said reflectivity peak in a wavelength region in the invisible range and lower reflectivities than said reflective peak in a wavelength region between said two other wavelength regions, means for successively reading out corresponding pairs of output signals and reference data from said respective first and second memories and for transmitting successively these pairs to means for obtaining the difference between an output signal and corresponding reference data, means for accumulating the output of said difference obtaining means over the whole plurality of pairs, the judging means receiving the output of said accumulating means.

The above and further objects, features and advantages of the invention will becomes more apparent from the following description when the same is read with reference to the accompanying drawings, in which:

Fig. 1 is a graph for explaining the relative luminosity of man;

Fig. 2 is a graph showing the spectral reflectivity characteristic of an organic ink CF 5,150, a product of Toyo Ink Manufacturing Co., Ltd., in Japan, for example;

Fig. 3 is a graph showing the spectral reflectivity characteristic of an inorganic ink;

Fig. 4 is a view showing a print pattern of a printed matter;

Fig. 5 is a graph showing the spectral energy characteristic of a light source of a color copier;

Figs. 6 and 7 show an apparatus for inspecting printed matter;

Figs. 8 and 9 show a different apparatus for inspecting printed matter;

Fig. 10 is a graph showing the spectral energy characteristic of an ink which is excited by visible light and emits near-infrared radiation;

Fig. 11 is a graph showing the spectral energy characteristic of an ink which is excited by near-infrared radiation and emits near-infrared radiation;

Fig. 12 is a schematic showing of a further apparatus for inspecting printed matter;

Fig. 13 is a graph showing the spectral energy characteristic of an ink, a fluorescent ink SPD-3S, a product of Tokyo Shibaura Denki Kabushiki Kaisha, for example, which is excited by ultraviolet radiation and emits visible light;

Fig. 14 is a graph showing the spectral energy characteristic of an ink, a fluorescent ink SPD-120S, a product of Tokyo Shibaura Denki

Kabushiki Kaisha, for example, which is excited by ultraviolet radiation and emits near-infrared radiation;

Fig. 15 is a schematic showing of a further apparatus for inspecting printed matter;

Fig. 16 is a graph showing the spectral reflectivity characteristic of a further different ink;

Fig. 17 is a view showing a print pattern of a different printed matter;

Fig. 18 is a schematic showing of a further apparatus for inspecting printed matter;

Fig. 19 is a graph showing the transmittance characteristic of an optical filter;

Fig. 20 is a graph showing the spectral reflectivity characteristic of a further different ink; and

Fig. 21 is a block diagram showing an embodiment of the invention.

Fig. 1 shows the relation between the relative luminosity of the eye of man and the wavelength. As is seen from the Figure, the visible wavelength range is approximately from 380 nm to 700 nm. That is, the electromagnetic waves of the wavelengths in this range constitute visible light, which can be sensed by the eye of man when it is reflected or radiated by the ink. An inorganic ink has a character that it can reflect only light in the visible range as shown in Fig. 3. However, among organic inks which are used for color copying machine, for instance, there is one having a reflectivity characteristic covering an invisible range as shown in Fig. 2. In this characteristic, the reflectivity is high in the neighborhood of 520 nm and in the infrared region above 700 nm while it is low for the rest of the wavelength range.

The human eye, however, is hardly sensitive to wavelengths near infrared, so that with an ink having the characteristic of Fig. 2 only wavelengths in the neighborhood of 520 nm which correspond to green are seen. Now, a printed matter 4 as shown in Fig. 4 will be considered, in which a portion labeled A has an impression of an organic ink having a character as shown in Fig. 2 while a portion labeled B has an impression of the inorganic ink of the character shown in Fig. 3. In this case, of the light reflected from the portion A components in a portion A' in Fig. 2 are seen, while of the reflected light from the portion B components in a portion B' in Fig. 3 are seen. The portions A and B are seen substantially as the same color. However, when the printed matter of Fig. 4 is color-copied, a different color results for the portion A though the same color is reproduced for the portion B. This results because the light source which is used with a color copier has a spectral characteristic as shown in Fig. 5, with the energy being higher for the near-infrared region rather than for the visible region (i.e., 380 to 700 nm). The inorganic ink in the portion B has no influence on a red-sensing section in the color copier, but the organic ink in the portion B has an effect that this portion B were red. Further, all inorganic color inks used with color copiers have high reflectivity in the infrared range, and substantially no ink having high reflectivity in an infrared region above 700 nm is used for printing purposes. In the case of organic ink, the reflectivity in an infrared region becomes high. Thus, by making use of these facts, reliable judgement of a printed matter as to whether it is true or false can be obtained.

Figs. 6 and 7 show a judging apparatus, which can make a decision as to whether a printed paper sheet as shown in Fig. 4, e.g., a bank note, is authentic or counterfeit.

As shown in Fig. 6, a bank note 4, the printing of which is done in the manner as shown in Fig. 4, is conveyed on a conveyor belt (not shown) in the direction of arrow 7. The bank note 4 is illuminated by light, which is projected from an illumination lamp 8. The illumination light contains energy in the visible range and also in the infrared range. Light reflected by the bank note 4 is coupled through a focusing lens 9, a near-infrared filter 10, which passes wavelengths of near-infrared region, and an aperture unit 11 to a photoelectric converter 12. The aperture of the aperture unit 11 serves to determine the resolution in the direction of transport of the bank note, the resolution in the direction perpendicular to the direction of transport of the bank note and a field of view. A light source 14 and a light receiver 15 are provided on the opposite sides of the path of the bank note 4 respectively. The light source 14 and light receiver 15 constitute a bank note passage detector, which serves to determine the timing of reading of signal from the photoelectric converter 12. The output signal of the bank note passage detector 14, 15 is fed to a sequence control circuit 16 which will be described later in detail. The output signal of the photoelectric converter 12 is amplified by an amplifier 13 to be fed to analog memories 17 and 17' as shown in Fig. 7. Of the output of the amplifier 13, data representing the quantities of reflected light from the portions A and B of the bank note 4, for instance, are stored in the analog memories 17 and 17' under the control of a signal produced from the control circuit 16 in a timed relation to the passage of the bank note 4 through the bank note passage detector 14, 15. The output of the analog memory 17 is fed to a difference circuit 21 and also to a comparator 19. The output of the analog memory 17' is fed to the difference circuit 21 and also to a comparator 19'. An output signal of reference level generator 18 is supplied to the comparators 19 and 19'. The output of the difference circuit 21 and the outputs of the comparators 19 and 19' are fed to a judgement circuit 20.

The operation of the construction of Figs. 6 and 7 as described above will now be described. When the bank note 4 passes through the bank note passage detector 14, 15, the data representing the quantity of infrared radiation reflected from the portion A of the bank note 4 is stored in the analog memory 17, while the data representing the quantity of infrared radiation reflected from the portion B of the bank note 4 is stored in the analog memory 17'. When the writing of data in the analog memories 17 and 17' is completed, the difference between the outputs

of the analog memories 17 and 17' is calculated in the difference circuit 21. If the bank note 4 is an authentic one, in which the portion A has an impression of organic ink, a large quantity of near-infrared radiation is reflected from the portion A, while substantially no near-infrared radiation is reflected from the portion B. In this case, an output from the difference circuit 21 calculating the output difference of the memories 17, 17' becomes "1". If the bank note 4 is what is copied with a color copier, large quantities of infrared radiation are reflected from both the portions A and B, and the difference circuit 21 produces a "0" output. If the bank note 4 is a counterfeit one obtained by printing, substantially no infrared radiation or high infrared radiation is reflected from both the portions A and B, and the difference circuit 21 again produces a "0" output. The judging circuit 20 thus judges the detected bank note 4 to be an authentic one when and only when the output of the difference circuit 21 is "1".

The outputs of the analog memories 17 and 17' are fed to the respective comparators 19 and 19' for level comparison with respect to a reference level provided from the reference level generator 18. In the comparator 19, the level of the infrared radiation quantity from the portion A is checked as to whether it is within a level range U in Fig. 2. If it is detected that the level is within the level range U, the bank note 4 is judged to be an authentic one. In the case of, for instance, a counterfeit bank note produced by printing using inorganic ink, less infrared radiation is reflected so that the compared level is below the level range U. In this case, the counterfeit bank note thus is judged to be as such. In the comparator 19', the level of the infrared radiation quantity from the portion B is checked as to whether it is within the level range L in Fig. 3. If it is detected that the level is within the level range L, the bank note is judged to be an authentic one. In the case of, for instance, a counterfeit bank note produced by copying with a color copier or that produced by organic ink printing, more than proper quantity of infrared radiation is reflected from the portion B, so that the compared level is above the level range L. In this case, the counterfeit bank note thus is judged to be as such.

In the manner as described above, counterfeit bank notes such as those produced by printing or by copying with a color copier can be reliably discriminated.

As shown in Fig. 8, a bank note 4, a print of which is again as shown in Fig. 4 with its portion A having a green impression of an organic ink and its portion B having a green impression of an inorganic ink, is conveyed on a conveyor belt (not shown) in the direction of arrow 7. The bank note 4 is illuminated by light or electromagnetic wave projected from an illumination lamp 8 and containing energy in the visible and infrared ranges. Light reflected from the bank note 4 is coupled through a focusing lens 9 to a blue dichroic mirror 36. The blue dichroic mirror 36 reflects only blue light while allowing light of the other wavelengths to pass. Light transmitted through the blue dichroic mirror 36 is coupled to a green dichroic mirror 37, which reflects only green light. Light transmitted through the green dichroic mirror 37 is coupled to a red dichroic mirror 38, which reflects only red light of 600 to 650 nm.

Light transmitted through the red dichroic mirror 38 is coupled through a near-infrared filter 30, which transmits wavelengths of near-infrared region, and an aperture unit 31 to a photoelectric converter 32. Light reflected by the blue dichroic mirror 36 is coupled through a blue filter 39 and an aperture unit 40 to a photoelectric converter 41. Light reflected by the green dichroic mirror 38 is coupled through a green filter 43 and an aperture unit 44 to a photoelectric converter 45. Light reflected by the red dichroic mirror 38 is coupled through a red filter 47, which transmits wavelengths of 600 to 650 nm, and an aperture unit 48 to a photoelectric converter 49. The aperture units 31, 40, 44 and 48 serve to determine the resolutions and field of view as in the preceding apparatus. Further, like the preceding apparatus a light source 14 and a light receiving element 15 are provided to constitute a bank note passage detector which serves to determine the timing of reading.

The outputs of the photoelectric converters 32, 41, 45 and 49 are amplified by respective amplifiers 33, 42, 46 and 50 to detect reflected infrared, blue, green and red radiation quantities respectively. These output signals of the amplifiers 33, 42, 46 and 50 are fed to analog memories 51 to 58 shown in Fig. 9. More particularly, data representing the quantities of infrared radiation from the portions A and B are stored in the respective analog memories 51 and 52, those of red radiation from the portions A and B are stored in the analog memories 53 and 54, those of green radiation from the positions A and B are stored in the analog memories 55 and 56, and those of blue radiation from the portions A and B are stored in the analog memories 57 and 58.

After the writing of data in these analog memories 51 to 58 is completed, judgement as to whether the bank note is authentic or counterfeit is done in the following way. Difference circuits 61 to 64 compare the quantities of radiation reflected from the A and B portions for the respective colors. For the infrared component of light, like the preceding apparatus, the quantity of radiation from the portion A is large while that from the portion B is small if the bank note is an authentic one. With an authentic bank note the difference circuit 61 thus produces a "1" output, so that a judging circuit 74 judges the bank note to be authentic. In case of a counterfeit bank note obtained by copying with a color copier, large quantities of infrared radiations are reflected from both the portions A and B. Thus, the difference circuit 61 produces this time a "0" output so that the judging circuit 74 judges the bank note to be a counterfeit one. In case of a counterfeit bank note obtained by printing using inorganic or organic ink, less or large quantities of infrared radiation

are reflected from both the portions A and B. Thus, the difference circuit 61 again produces this time a "0" output so that the judging circuit 74 judges the bank note to be counterfeit.

The difference circuit 62 calculates the difference between the quantities of the red component of light reflected from the portions A and B. With an authentic bank note, neither A nor B portion reflects any red component of light, where the inks used for these portions are of the characteristics of Figs. 2 and 3, in both of which a spectral reflectivity peak occurs in the green region. In this case, the difference circuit 62 thus produces a "0" output so that the judging circuit 74 judges the bank note to be authentic. With a counterfeit bank note obtained by copying with a color copier using an ink which has a spectral reflectivity peak in the red region, however, the peak is shifted toward the red region for the portion A although the same red color as in the original can be reproduced for the portion B. In this case, therefore, the difference circuit 62 produces a "1" output.

The difference circuit 63 calculates the difference between the quantities of the green component of light reflected from the portions A and B. With an authentic bank note, there is no difference between the quantities of reflected green light from the portions A and B, as is seen from Figs. 2 and 3. In this case, the difference circuit 63 thus produces a "0" output. With a counterfeit bank note obtained by copying with a color copier, the color of the portion A is rather reddish although the color of the portion B is the same as in the original as is recognizable even by the visual inspection. That is, the spectral reflectivity peak is shifted from the green region toward red (i.e., toward the right side in Fig. 2). Consequently, a difference is detected between the quantities of reflected green light from the A and B portions, causing the difference circuit 63 to produce a "1" signal so that the judging circuit 74 judges the counterfeit bank note as such.

The difference circuit 64 detects a difference for the blue component of light. Again with an authentic bank note, there is no difference in the reflected red light between the portions A and B. With a counterfeit bank note obtained by copying with a color copier, in which case the spectral reflectivity peak is shifted toward red as mentioned earlier, a difference in the reflected green light is detected, causing the difference circuit 64 to produce a "1" output so that the judging circuit 74 judges the counterfeit bank note as such.

A reference level generator 65 and comparators 66 and 67 respectively have the same construction and function as the reference level generator 18 and comparators 19 and 19' in the preceding apparatus of Fig. 7, so these components are not described.

While the above apparatus have concerned the case of a green organic ink in which the reflectivity is high in the neighborhood of 520 nm and in the near-infrared region, similar effects may of course be obtained in case of an organic ink of any other color so long as the reflectivity is high in the infrared region.

Further, an organic ink having a reflectivity characteristic in which the reflectivity is high in a certain color region and in the near-infrared region has been concerned, this is by no means limitative. For example, in case of an ink, the reflectivity of which is high for a certain color region and in the long wavelength region in the visible region, short wavelength region, or the ultraviolet region, it is possible to make judgement similar to the above apparatus. In case of using the ultraviolet region, the judgement may be done by making the detection of the quantity of reflected light in the neighborhood of 400 nm or by making use of the fact that a shift toward violet results when color separation is done. In general, the effects can be obtained in case of any ink, the reflectivity of which is high in the invisible regions or in a low luminosity region in the visible range.

In the preceding apparatus, the authenticity of a printed matter, for which two different kinds of ink which have substantially the same spectral reflectivity characteristic in the visible range but have different spectral reflectivity characteristics in the invisible or low luminosity range, is judged by detecting the quantities of reflected light from these two inks. Thus, a false or counterfeit paper sheet obtained by copying with a color copier can be readily discriminated as such due to lack in the fidelity of color reproduction. Further, color copies can be reliably judged as such because of the high reflectivity in the infrared region. Further, a replica obtained by printing can be reliably discriminated as such.

Further, not only the judgement of the authenticity but also the judgement of different kinds of printed matter can be obtained by varying the place of presence of ink or the color of ink.

Now, a different apparatus for discriminating a counterfeit printed matter obtained by a printing process will be described. Generally, light emitters which absorb light energy at certain wavelengths and emit energy at other wavelengths are known. These light emitters include those, which are excited by visible light and emit near-infrared radiation, and those, which are excited by near-infrared radiation of certain wavelengths and emit near-infrared radiation of other wavelengths.

Fig. 10 shows a spectral characteristic of a light emitter ink, which is excited by visible light and emits near-infrared radiation. Fig. 11 shows a spectral characteristic of a light emitter ink, which is excited by near-infrared radiation of certain wavelengths and emits near-infrared radiation of other wavelengths. With either of these light emitters, the radiation is not sensitive to the human eye because it is in a near-infrared wavelength range above the upper limit of the visible wavelength range. With a printed matter, in which a mixture of either of such inks and an inorganic ink is used for printing in the portion A while the inorganic ink having the characteristic of Fig. 3 is used for the portion B as in Fig. 4, both the

portions A and B are seen to the human eye that they are entirely of the same color. However, when the printed matter is copied with a color copier, a different color results for the portion A though the same color is reproduced for the portion B. This results from the ground as described earlier. If the copy of the printed matter is a counterfeit paper money, it can thus be discriminated as such by the human eye. Fig. 12 shows a counterfeit bank note discriminating apparatus for a bank note using a blend ink containing a near-infrared emission ink in a pattern of Fig. 4 as noted above.

As shown in Fig. 12, a bank note 4, which has a print pattern as shown in Fig. 4, is conveyed on a conveying belt (not shown) in the direction of arrow 7. The bank note is illuminated by light from an illumination light source 80. Where the near-infrared emission ink has a character as shown in Fig. 10, the light source projects only visible light of 520 nm peak. Where the near-infrared emission ink is of a character as shown in Fig. 11, the light source projects only radiation in the infrared excitation wavelength range of 800 nm to 900 nm. When the portion A of the bank note is illuminated by light from the light source 80 shown in Fig. 10 or Fig. 11, it emits near-infrared radiation of 700 to 900 nm or 700 to 800 nm. The near-infrared radiation from the bank note 4 is coupled through a focusing lens 81, a near-infrared filter 82, which allows only the near-infrared components to pass, and an aperture unit 83 to a photoelectric converter 84. The aperture of the aperture unit 83 serves to determine the resolution in the direction of transport of the bank note, the resolution in the direction perpendicular to the direction of transport of the bank note and the field as mentioned earlier. Further, a light source 14 and a light receiver 15 form a bank note passage detector serving to determine the timing of reading data from the photoelectric converter 84. The output signal from the bank note passage detector is fed to a control circuit 85 to be described later in detail. The output signal of the photoelectric converter 84 is amplified by an amplifier 86 to be fed to an analog memory 87. Of the output of the amplifier 86, data representing the quantity of near-infrared radiation from the portion A of the bank note 4 is stored in the analog memory 87 in timed relation to the passage of the bank note 4 through the bank note passage detector 14, 15. The output of the analog memory 87 is fed to a comparator 88. An output from reference level generator 89 is supplied to the comparator 88, and the output thereof is fed to a judging circuit 90.

The operation of the construction of Fig. 12 described above will now be described. When the bank note 4 passes through the bank note passage detector 14, 15, the data representing the quantity of near-infrared radiation from the portion A of the bank note is stored in the analog memory 87. The output of the analog memory 87 is compared in the comparator 88 with the reference level provided from the reference level generator 89. More particularly, the comparator 88 makes a check as to whether the level of the quantity of near-infrared radiation from the portion A is above a predetermined level. If the compared level is above the predetermined level, the bank note is judged to be an authentic one. With a counterfeit bank note obtained by printing, no near-infrared radiation is detected so that the compared level is below the predetermined level. In this case, the counterfeit bank note is thus judged as such. With a counterfeit bank note obtained by copying with a color copier, the compared level of near-infrared ray from the color toner is again below the level of the near-infrared ray radiation by the excitation so that the bank note is judged to be counterfeit.

As has been shown, with the above apparatus it is possible to reliably detect a counterfeit bank note obtained by copying with a color copier or that obtained by printing.

Among the light emitters, there are also those which, unlike those described in connection with the preceding apparatus, are excited by ultraviolet radiation and emit visible light or are excited by ultraviolet radiation and emit near-infrared radiation.

Fig. 13 shows a spectral characteristic of a light emitter ink, which is excited by ultraviolet radiation of 300 to 400 nm and emits visible light of 450 to 550 nm. Fig. 14 shows a spectral characteristic of a light emitter ink, which is excited by ultraviolet radiation of 150 nm peak and emits near-infrared radiation of 680 to 900 nm. A printed matter, in which a mixture of either of these inks with an inorganic ink having the characteristics of Fig. 3 is used for printing in the portion A in Fig. 4, will now be considered. When such a printed matter or bank note is illuminated using an ultraviolet radiation source such as a commercially available mercury lamp, the portion A emits visible light so that one can recognize that the printing ink for the portion A contains a light emitter capable of emitting visible light. However, one cannot recognize that this printing ink also contains a light emitter capable of emitting near-infrared radiation. In other words, the visible light emitter is incorporated for the purpose of camouflaging. Fig. 15 shows a counterfeit bank note discriminating apparatus for a bank note using a blend ink as noted above.

As shown in Fig. 15, a bank note 4, which has a print pattern as shown in Fig. 4, is conveyed on a conveyor belt (not shown) in the direction of arrow 7. The bank note 4 is illuminated by light from an illumination light source 91 (e.g., a low pressure mercury lamp). When the bank note 4 is illuminated by light from the light source 91, the portion A emits visible light and near-infrared radiation. The visible light and near-infrared radiation from the bank note are coupled through a focusing lens 92 to a dichroic mirror 93, which reflects only visible light. Visible light reflected by the dichroic mirror 93, is coupled through an optical filter 94, which transmits only visible light emitted by the light emitter as mentioned above,

and an aperture unit 95 to a photoelectric converter 96. Light transmitted through the dichroic mirror 93 is coupled through an optical filter 97, which transmits only near-infrared radiation, and an aperture unit 98, to a photoelectric converter 99. The bank note passage detector 14, 15 has the same role as the one in the preceding apparatus of Fig. 12, and its output signal is fed to a control circuit 100 to be described later in detail. The outputs of the photoelectric converters 96 and 99 are amplified by respective amplifiers 101 and 102 to be fed to respective analog memories 103 and 104. From the outputs of the amplifiers 101 and 102, data representing the quantities of visible light and near-infrared radiation from the portion A of the bank note 4 are stored in the respective analog memories 103 and 104 under the control of a signal provided from the control circuit 100 in timed relation to the passage of the bank note 4 through the bank note passage detector 14, 15. The outputs of the analog memories 103 and 104 are fed to respective comparators 105 and 106. An output of reference level generator 107 is fed to the comparators 105 and 106, and the outputs thereof are fed to a judging circuit 108.

The operation of the construction of Fig. 15 described above will now be described. When the bank note 4 passes through the bank note passage detector 14, 15, the quantities of visible light and near-infrared radiation from the portion A of the bank note 4 are stored in the analog memories 103 and 104. The outputs of the analog memories 103 and 104 are compared in the comparators 105 and 106 with the reference level provided from the reference level generator 107. More particularly, the comparator 105 compares the level of the visible light quantity from the portion A with a certain fixed level, while the comparator 106 compares the level of the near-infrared radiation from the portion A with a certain fixed level. If both the compared levels are above the respective fixed levels, the bank note is judged to be an authentic bank note. With a counterfeit bank note in which neither visible light nor near-infrared radiation is emitted from the portion A or, in the worst case, only visible light is emitted from the portion A, the conditions mentioned above are not satisfied, so that the counterfeit bank note is judged as such. Further, a counterfeit bank note obtained by copying with a color copier is judged as such since neither visible light nor near-infrared radiation is emitted from the portion A.

As has been shown, with the above apparatus it is possible to reliably detect a counterfeit bank note obtained by printing or that obtained by copying with a color copier.

While the above apparatus concerned a printed matter where a light emitter capable of emitting both visible light and near-infrared radiation was used in the form of a mixture with the ordinary ink, where the individual light emitters are solely printed in different positions, the same effects may be obtained by altering the timing of the sample pulse from the control circuit 100 such that the sample pulse corresponds to the aforementioned positions. Further, with an ink capable of emitting near-infrared radiation, only the component parts for the near-infrared radiation may be used.

Further, in addition to the inspection of bank note for the authenticity thereof, discrimination of different kinds of bank notes may also be done by appropriately arranging a suitable number of detecting sections such that the relevant different kinds of ink are covered.

The preceding apparatus has concerned a case where two different inks which have different spectral reflectivity characteristics for the near-infrared region are used though the visible range reflective characteristic is the same. Among the light emitter inks, there is one, which has a spectral reflectivity characteristic as shown in Fig. 16. Here, there is a reflectivity peak in a certain portion of the visible wavelength region and also the reflectivity is increased on the long wavelength side of the peak noted above and is high for near-infrared. (In this case, it is necessary that the reflectivity h2 is increased on the long wavelength side of near 700 nm beyond the visible region peak h1.) A printed matter, which has an impression of such ink in a portion A of a sheet 4 as shown in Fig. 17, will now be considered. (The printed matter also uses an inorganic ink having the characteristic of Fig. 3, with the reflectivity being low for long wavelengths in the visible region and also in the near-infrared region.) When this printed matter is copied with a color copier, a color change results for the portion A to a greater extent than that which may result in case of an inorganic ink. This results because the light source used with the color copier provides higher energy for the long wavelength side than for the short wavelength side so that the red-sensitive section is affected to a greater extent by the ink in the portion A than by the inorganic ink.

Fig. 18 shows a further counterfeit bank note discriminating apparatus for a bank note such as that shown in Fig. 17.

As shown in Fig. 18, a bank note 4 which is like that shown in Fig. 17 is conveyed on a conveyor belt (not shown) in the direction of arrow 7. The bank note 4 is illuminated by light from an illumination lamp 109. The illumination light contains energy in the visible region and infrared region. Light reflected from the bank note 4 is coupled through a focusing lens 110 to an optical filter 111. The optical filter 111 reflects wavelengths longer than a wavelength in the neighborhood of a wavelength λ_3 in Fig. 16. Components of the incident light only in the neighborhood of the wavelength λ_3, these being reflected by the optical filter 111, are coupled through a filter 112 and an aperture unit 113 to a photoelectric converter 114. Meanwhile, light transmitted through the optical filter 111 is coupled to a second optical filter 115. The optical filter 115 reflects wavelengths longer than λ_2 in Fig. 16 to be coupled through a filter 116 and an aperture unit 117 to a photoelectric converter 118. Light transmitted

through the optical filter 115 is coupled through a third optical filter 119, which transmits only wavelengths in the neighborhood of λ_1 in Fig. 16, and an aperture unit 120 to a photoelectric converter 121. Fig. 19 shows the transmittance characteristics X, Y and Z of the optical filters 112, 116 and 119. The aperture units 113, 117 and 120 serve to determine the resolution in the direction of transport of the bank note and the resolution in the direction perpendicular to the direction of transport of the bank note. A light source 14 and a light receiver 15 constitute a bank note passage detector having the same function as in the previous apparatus. The output from the detector is fed to a control circuit 128 to be described later in detail. The output signals of the photoelectric converters 114, 118 and 121 are amplified by respective amplifiers 122, 123 and 124 to be fed to respective analog memories 125, 126 and 127. The quantities of the λ_3, λ_2 and λ_1 wavelength components of light reflected from the portion A of the bank note 4 are stored in the analog memories 125, 126 and 127 under the control of a signal provided from the control circuit 128 in a timed relation to the passage of the bank note 4 through the bank note passage detector 14, 15. The output of the analog memory 125 is fed to difference circuits 129 and 130 and also to a comparator 132. The output of the analog memory 126 is fed to difference circuits 130 and 131 and also to a comparator 133. The output of the analog memory 127 is fed to difference circuits 129 and 131 and also to a comparator 134. An output signal of reference level generator 135 is supplied to the comparators 132, 133 and 134. The outputs of the difference circuits 129 to 131 and the outputs of the comparators 132 to 134 are fed to a judging circuit 136.

The operation of the construction of Fig. 18 described above will now be described. When the bank note 4 passes through the bank note passage detector 14, 15, the quantities of the λ_3, λ_2 and λ_1 components of light reflected from the bank note 4 are stored in the analog memories 125 to 127. The difference circuit 129 calculates the difference between the outputs of the analog memories 125 and 127. If the bank note is authentic, more λ_3 component of light is reflected from the portion A than λ_1 component. In this case, the difference circuit 129 thus produces a "1" output. In the case of an inorganic ink, more λ_1 component of light is reflected than λ_3 component, so that the difference circuit 129 produces a "0" output. The judging circuit 136 thus judges the bank note to be an authentic one when the output of the difference circuit 129 is "1".

The difference circuit 131 calculates the difference between the outputs of the analog memories 126 and 127. If the bank note is authentic, more λ_1 component of light is reflected than λ_2 component. In this case, the difference circuit 131 thus produces a "1" output. The judging circuit 136 judges the bank note to be an authentic one when and only when both the difference circuits 129 and 131 produce a "1" output. That is, the bank note is judged to be authentic when and only when the quantity of the λ_1 component of light reflects is greater than the quantity of the λ_2 component and less than the λ_3 component.

As has been shown, with the above apparatus a counterfeit bank note can be reliably detected.

The preceding apparatus concerned a method of detection with respect to a single kind of ink. In case of a plurality of different inks in which the wavelengths λ_1, λ_2 and λ_3 shown in Fig. 16 are different, higher performance of detection can be realized with an electronic circuit as shown in Fig. 18 by providing an increased number of photoelectric converters in the optical system in correspondence to the number of wavelengths involved for the wavelength analysis.

Now an embodiment of the invention will be described with reference to Figs. 20 and 21. Among light emitter inks, there is one having a spectral reflectivity characteristic as shown in Fig. 20. If a printed matter, which uses such ink for a portion A as shown in Fig. 4, is reproduced, by copying with a color copier or by printing, the reproduced color will have a considerably different spectral reflectivity characteristic from that of the original due to the photosensitive characteristics of the color copier or characteristics of toner or depending upon the kinds of inks used for printing although it may be more or less similar to the original color. In this embodiment, a spectral reflectivity characteristic pattern for a certain portion or portions of the wavelength range is previously obtained from the authentic bank note, and the spectral reflectivity pattern read out from the bank note tested in compared with the standard pattern. If the difference between the two patterns is within a certain value, the bank note is judged to be an authentic one. Fig. 21 shows the circuit construction of this embodiment. The circuit includes photoelectric converters 151 to 158. Like the apparatus of Fig. 8, near-infrared (NI), red (R), orange (O), yellow (Y), green (G), blue (B), magenta (M) and violet (V) components of reflected light, these components being successively separated in the mentioned order through dichroic mirrors, are coupled through filters and aperture units to the respective photoelectric converters 151 to 158. The outputs of the photoelectric converters 151 to 158 are amplified by respective amplifiers 161 to 168 to be stored in an analog memory 170. If the bank note is inspected for three different portions, data from these three portions are successively stored in the analog memory 170. Like the previous apparatus of Fig. 8, the writing is done under the control of a timing signal produced from a control circuit 171 according to a signal from bank note passage detector 14, 15.

When the writing of the spectral reflectivity characteristic data for the individual inspection areas of the bank note in the analog memory 170 is completed, data of the near-infrared component from the first inspection area is read out from the analog memory 170 and fed to a difference circuit 172 under the control of a timing

signal from the control circuit 171. At this time, data for the near-infrared component from the first inspection area, which has been obtained from the authentic bank note and stored in advance in a reference spectral reflectivity pattern memory 173, is read out and supplied to the difference circuit 172 under the control of timing signal from the control circuit 171. The difference circuit 172 calculates the difference between the reference data and inspected data and provides the absolute value of the difference thus obtained. The output of the difference circuit 172 is set in an adder 174. Subsequently, data of the red component from the first inspection area is read out from the analog memory 170 and fed to the difference circuit 172. At the same time, the red component data for the first inspection area is read out from the reference spectral reflectivity pattern memory 173 and supplied to the difference circuit 172. The difference circuit 172 again calculates the difference, and the absolute value thereof is added to the difference data for the near-infrared component in the adder 174. Likewise, the differences between the other components, i.e., orange, yellow, green, blue, magenta and violet components, for the first inspection area and the corresponding data of the reference spectral reflectivity pattern are also obtained, and their absolute values are accumulated in the adder 174. When the above processing of the component data for the first inspection area is completed, the data of the adder 174 is fed to a judging circuit 175. The judging circuit 175 judges whether the total difference data from the adder 174 is within a predetermined value.

When the judgement for the first inspection area is ended, similar operation of calculating differences and adding together the absolute difference values thereof for the second inspection area is caused to commence with the near-infrared component first. At this time, the corresponding authentic bank note data for the second inspection point are of course provided from the reference spectral reflectivity pattern memory 173. When the processing of data for the second inspection area is completed, the total difference data obtained in the adder 174 is fed to the judging circuit 175, whereby whether it is within a predetermined value is judged. Likewise, for the third inspection area the total difference data is obtained and fed to the judging circuit 175 for judgement as to whether it is within a predetermined value.

When the judgement for all the inspection areas is completed, the judging circuit 175 executes a final judgement as to whether there are two or more inspection areas, for which the total difference data are above the respective predetermined values. If there are two or more such inspection areas, the judging circuit 175 judges the bank note to be a counterfeit one. The above judgement operation is effective for eliminating or at least reducing the possibility of erroneously judging an authentic bank note to be a counterfeit one in such a case as when the spectral reflectivity characteristic is changed by contamination. For more stringent judgement, the number of inspection spots may be increased, and the final judgement to be an authentic bank note may be rendered when and only when the data for all the inspection spots are within respective predetermined values. Further, where very stringent inspection is necessary such as when a large number of counterfeit bank notes are circulated, the judgement level of the judging circuit 175, i.e., the level to which the level of the output of the adder 174 is compared (i.e., the predetermined values in the previous description) may be made selectable to one of a plurality of different levels.

Further, discrimination of different kinds of bank notes can be simultaneously effected by providing reference spectra reflectivity characteristic patterns for the individual kinds of bank notes and by arranging such that the most similar reference pattern may be selected from the comparison of the individual reference patterns with the pattern obtained from each inspected bank note.

As has been shown, with the above embodiment reliable judgement can be obtained.

While a preferred embodiment of the invention has been described above, it may be used either independently or in suitable combinations. In the latter case, more reliable and accurate judgement can be obtained. Also, a variety of combinations are possible for various purposes.

As has been described in detail in the foregoing, according to the invention a printed matter, in which an ink featuring a reflectivity characteristic or emittance characteristic in a wavelength region outside the visible range is used, can be reliably inspected for its authenticity by irradiating the printed matter with electromagnetic waves.

Claim

An apparatus for inspecting printed matter comprising means for irradiating at least a section of the printed matter with electromagnetic radiation of a predetermined wavelength range, means for forming a plurality of electric signals representing the spectral energy distribution of the electromagnetic radiation reflected from the inspected printed matter, and inspecting means including a first memory (170) for storing said plurality of electric signals and judging means for determining whether the inspected printed matter is an authentic one on the basis of the electric signals in said first memory (170), characterized in that

— said means for forming said plurality of electric signals includes a like plurality of photoelectric converters (151—158), and

— said inspecting means further includes a second memory (173) in which a like plurality of reference data is stored, said plurality of reference data representing the spectral distribution of the reflectivity of authentic printed matter and having a reflectivity peak in a wavelength region in the

visible range, higher reflectivities than said reflectivity peak in a wavelength region in the invisible range and lower reflectivities than said reflectivity peak in a wavelength region between said two other wavelength regions, means (171) for successively reading out corresponding pairs of output signals and reference data from said respective first and second memories and for transmitting successively these pairs to means (172) for obtaining the difference between an output signal and corresponding reference data, means (174) for accumulating the output of said difference obtaining means (172) over the whole plurality of pairs, the judging means receiving the output of said accumulating means (174).

Patentanspruch

Gerät zur Überprüfung von Druckerzeugnissen, umfassend eine Einrichtung zum Bestrahlen mindestens eines Teils eines Druckerzeugnisses mit elektromagnetischer Strahlung eines vorbestimmten Wellenlängenbereichs, eine Einrichtung zum Erzeugen einer Anzahl von elektrischen Signalen, welche die spektrale Energieverteilung der vom untersuchten Druckerzeugnis reflektierten elektromagnetischen Strahlung repräsentieren, und eine Überprüfungseinrichtung mit einem ersten Speicher (170) zum Speichern der Anzahl elektrischer Signale sowie eine Entscheidungs- oder Bewertungseinrichtung zum Bestimmen, ob das untersuchte Druckerzeugnis echt ist, auf der Grundlage der elektrischen Signale im ersten Speicher (170), dadurch gekennzeichnet, daß

— die Einrichtung zum Erzeugen der Anzahl elektrischer Signale eine gleiche Anzahl von photoelektrischen Wandlern (151—158) aufweist und

— die Überprüfungseinrichtung weiterhin einen zweiten Speicher (172), in welchem eine gleiche Anzahl von Bezugsdaten gespeichert ist, welche die spektrale Verteilung der Reflexionskraft eines echten Druckerzeugnisses repräsentieren, das eine(n) Reflexionskraftspitze oder -peak in einem Wellenlängenbereich innerhalb des sichtbaren Bereichs, höhere Reflexionskräfte als die Reflexionskraftspitze in einem Wellenlängenbereich innerhalb des unsichtbaren Bereichs und niedrigere Reflexionskräfte als die Reflexionskraftspitze in einem zwischen den beiden anderen Wellenlängenbereichen liegenden Wellenlängenbereich aufweist, eine Einrichtung (171) zum aufeinanderfolgenden Auslesen entsprechender Paare von Ausgangssignalen und Bezugsdaten aus den jeweiligen ersten und zweiten Speichern und zum aufeinanderfolgenden Übertragen dieser Paare zu einer Einrichtung (172) für die Ableitung der Differenz zwischen einem Ausgangssignal und (einer) entsprechenden Bezugsdaten-(einheit) und eine Einrichtung (174) zum Sammeln oder Aufspeichern des Ausgangssignals der Differenzableitungseinrichtung (172) über die gesamte Anzahl der genannten Paare umfaßt, wobei die Bewertungseinrichtung des Ausgangssignal von der Aufspeichereinrichtung (174) abnimmt.

Revendication

Appareil d'inspection d'un élément imprimé, comprenant un dispositif d'irradiation d'un tronçon au moins de l'élément imprimé avec un rayonnement électromagnétique d'une plage prédéterminée de longueurs d'onde, un dispositif destiné à former plusieurs signaux électriques représentant la distribution d'énergie spectrale du rayonnement électromagnétique réfléchi par l'élément imprimé inspecté, et un dispositif d'inspection comprenant une première mémoire (170) destinée à mémoriser plusieurs signaux électriques et un dispositif de jugement destiné à déterminer si l'élément imprimé inspecté est authentique en fonction des signaux électriques se trouvant dans la première mémoire (170), caractérisé en ce que

— le dispositif destiné à former plusieurs signaux électriques comprend un nombre analogue de convertisseurs photoélectriques (151—158), et

— le dispositif d'inspection comporte en outre une seconde mémoire (173) dans laquelle un nombre analogue de données de référence est conservé, les données de référence représentant la répartition spectrale du pouvoir réflecteur de l'élément imprimé authentique et ayant un pic de pouvoir réflecteur dans une région de longueurs d'onde se trouvant dans la plage visible, des pouvoirs réflecteurs plus élevés que le pic de pouvoir réflecteur dans une région de longueurs d'onde se trouvant dans la partie non visible et des pouvoirs réflecteurs plus faibles que le pic de pouvoir réflecteur dans une région de longueurs d'onde comprise entre les deux autres régions de longueurs d'onde, un dispositif (171) destiné à lire successivement des paires correspondantes de signaux de sortie et de données de référence provenant de la première et de la seconde mémoire respective et à transmettre successivement ces paires à un dispositif (172) destiné à former la différence entre un signal de sortie et des données correspondantes de référence, un dispositif (174) destiné à accumuler les signaux de sortie du dispositif (172) d'obtention de différence pour l'ensemble des paires, le dispositif de jugement recevant le signal de sortie du dispositif d'accumulation (174).

FIG. 1

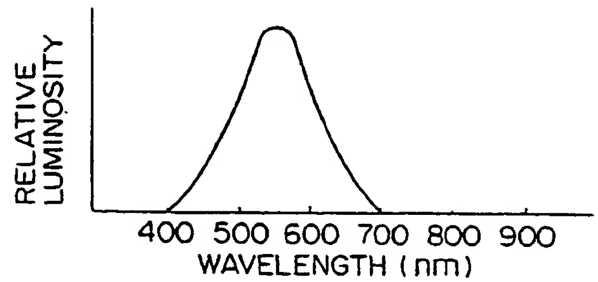


FIG. 2

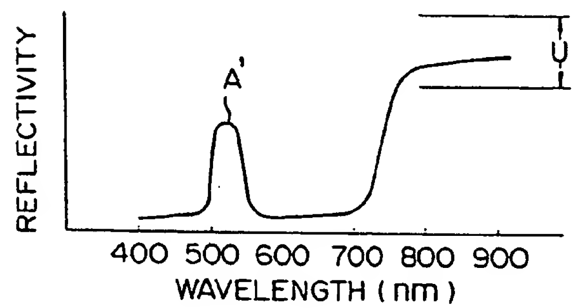


FIG. 3

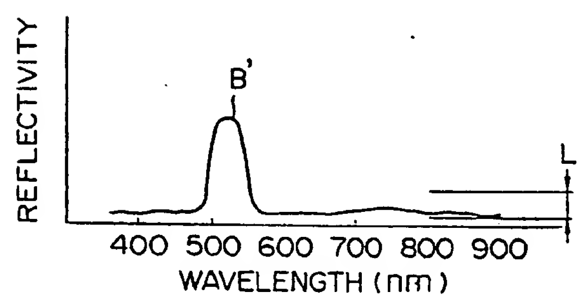
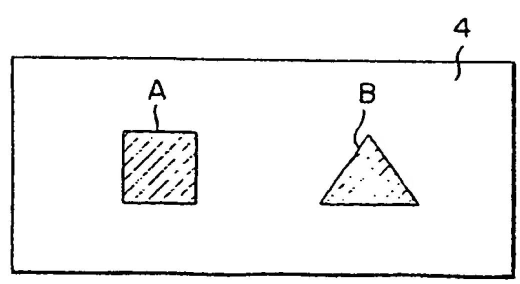
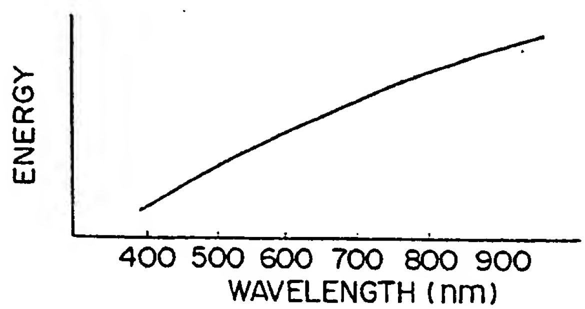


FIG. 4



F I G. 5


ENERGY
400 500 600 700 800 900
WAVELENGTH (nm)

F I G. 6

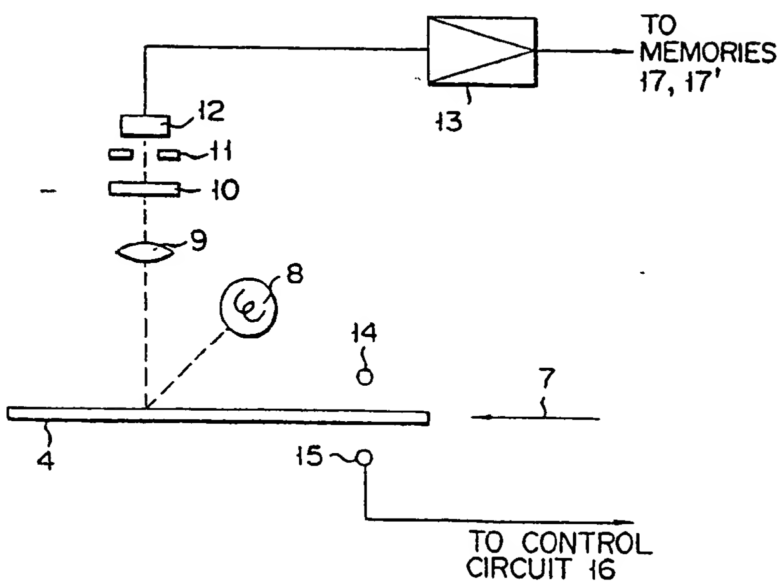
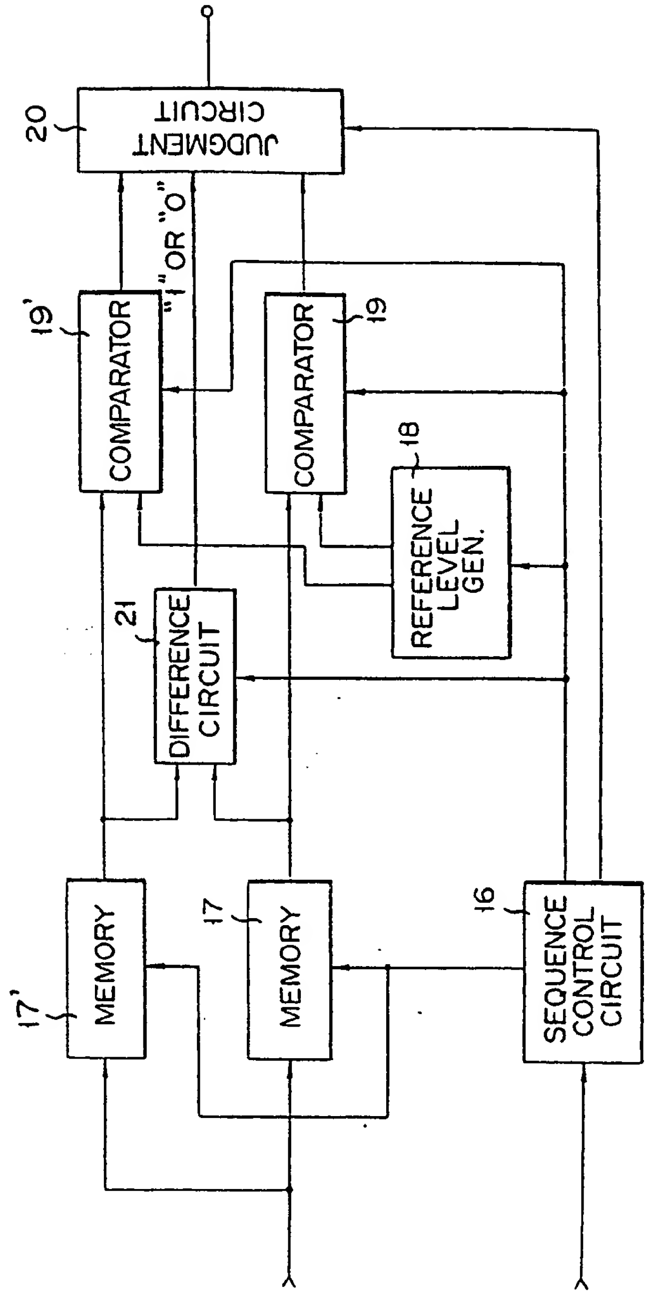

TO MEMORIES 17, 17'
13
12
11
10
9
8
14
7
4
15
TO CONTROL CIRCUIT 16

FIG. 7


JUDGMENT CIRCUIT
20
COMPARATOR
19'
"1" OR "0"
COMPARATOR
19
18
REFERENCE LEVEL GEN.
21
DIFFERENCE CIRCUIT
MEMORY
17'
17
MEMORY
16
SEQUENCE CONTROL CIRCUIT

F I G. 8

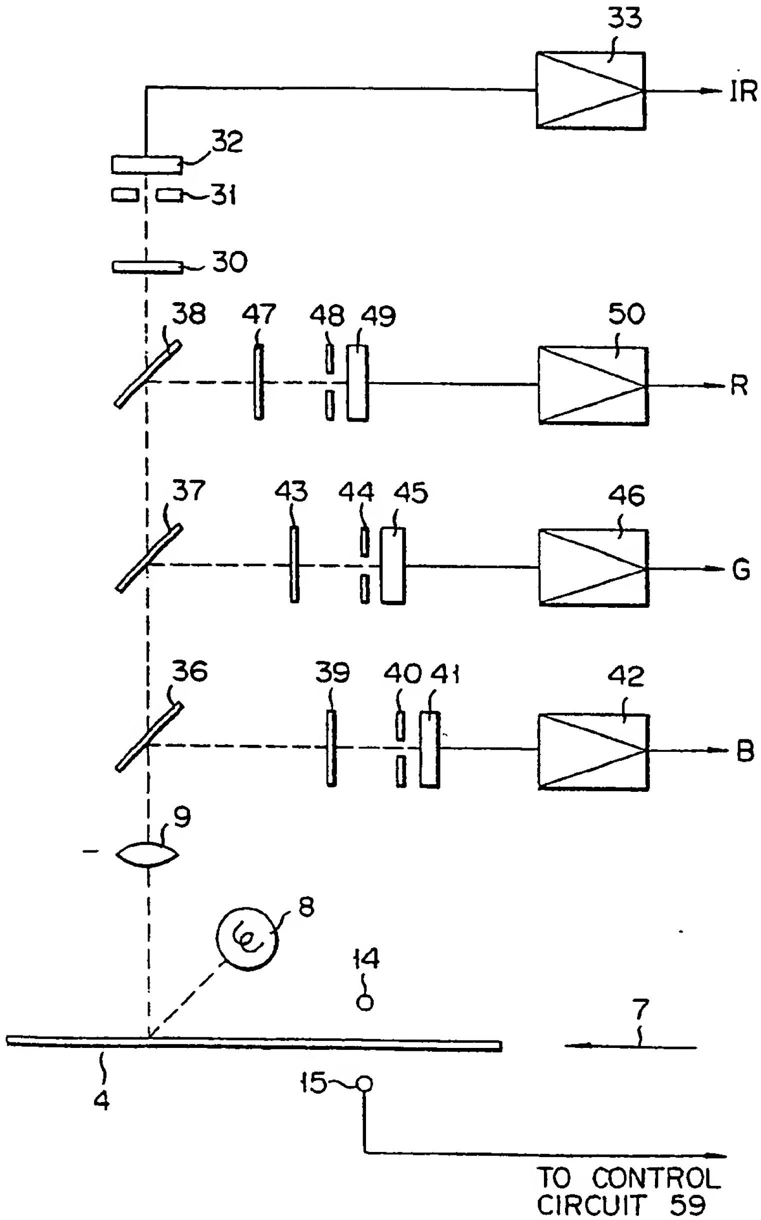

33
IR
32
31
30
38
47
48
49
50
R
37
43
44
45
46
G
36
39
40
41
42
B
9
8
14
7
4
15
TO CONTROL
CIRCUIT 59

FIG. 9

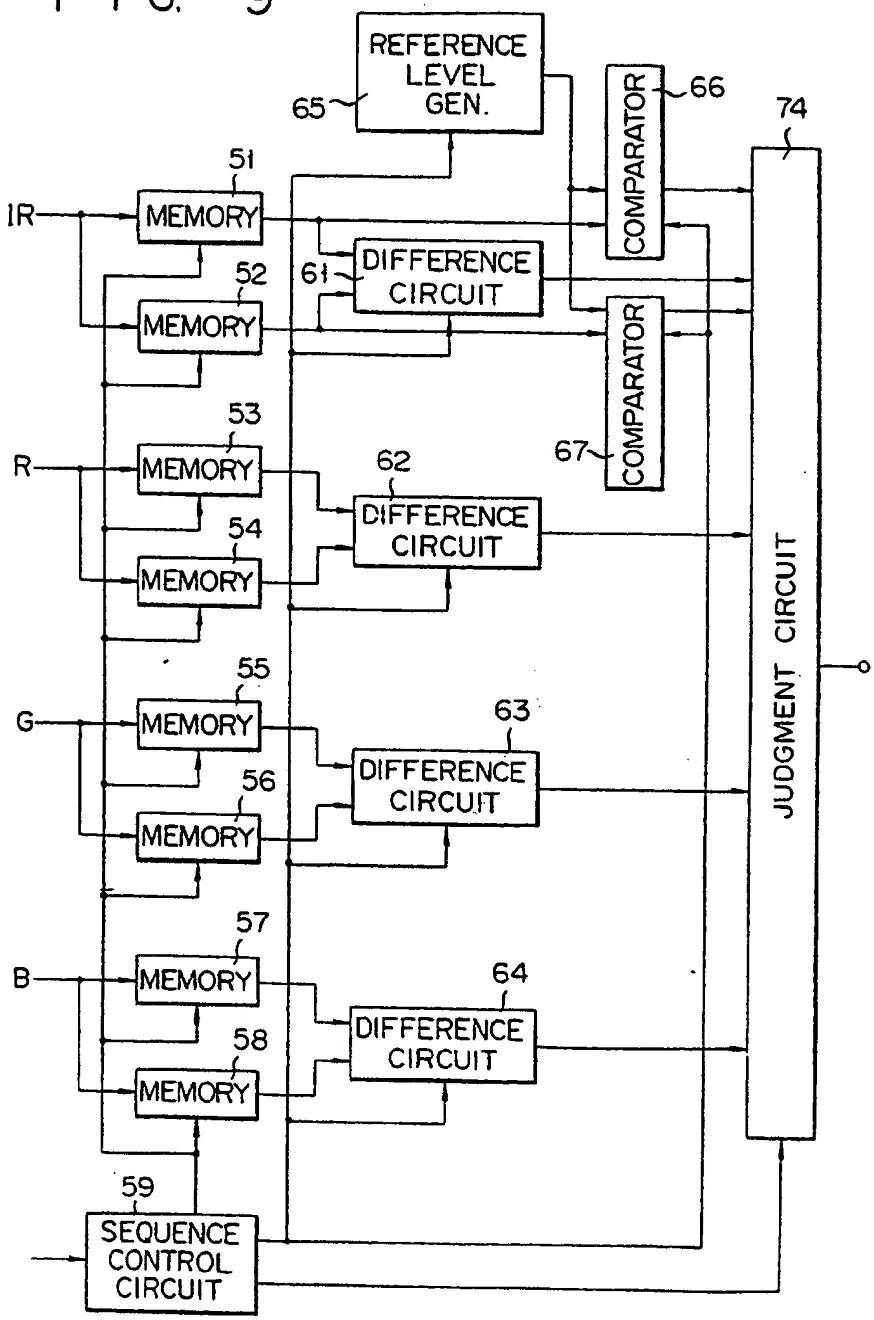

REFERENCE LEVEL GEN.
65
66
74
COMPARATOR
51
IR
MEMORY
52
MEMORY
DIFFERENCE CIRCUIT
61
COMPARATOR
67
53
R
MEMORY
62
DIFFERENCE CIRCUIT
54
MEMORY
JUDGMENT CIRCUIT
55
G
MEMORY
63
DIFFERENCE CIRCUIT
56
MEMORY
57
B
MEMORY
64
DIFFERENCE CIRCUIT
58
MEMORY
59
SEQUENCE CONTROL CIRCUIT

FIG. 10

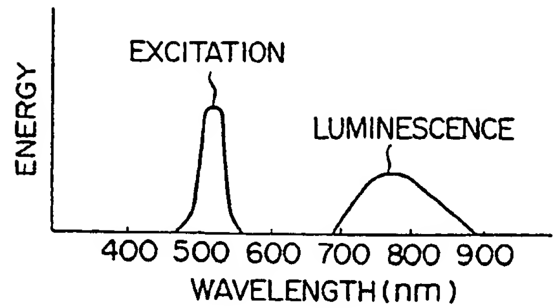


FIG. 11

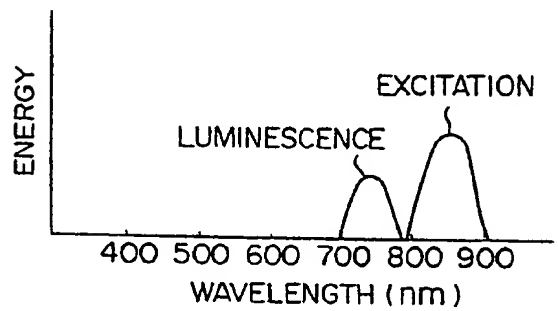


FIG. 13

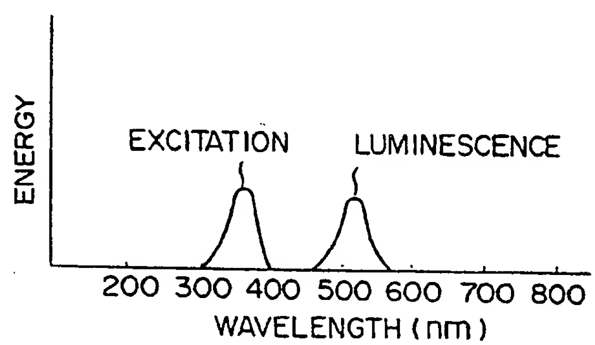
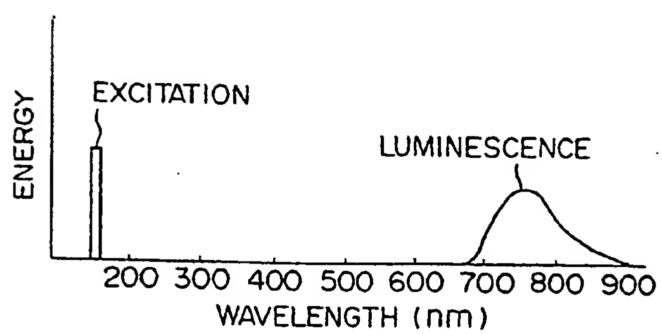


FIG. 14



F I G. 12

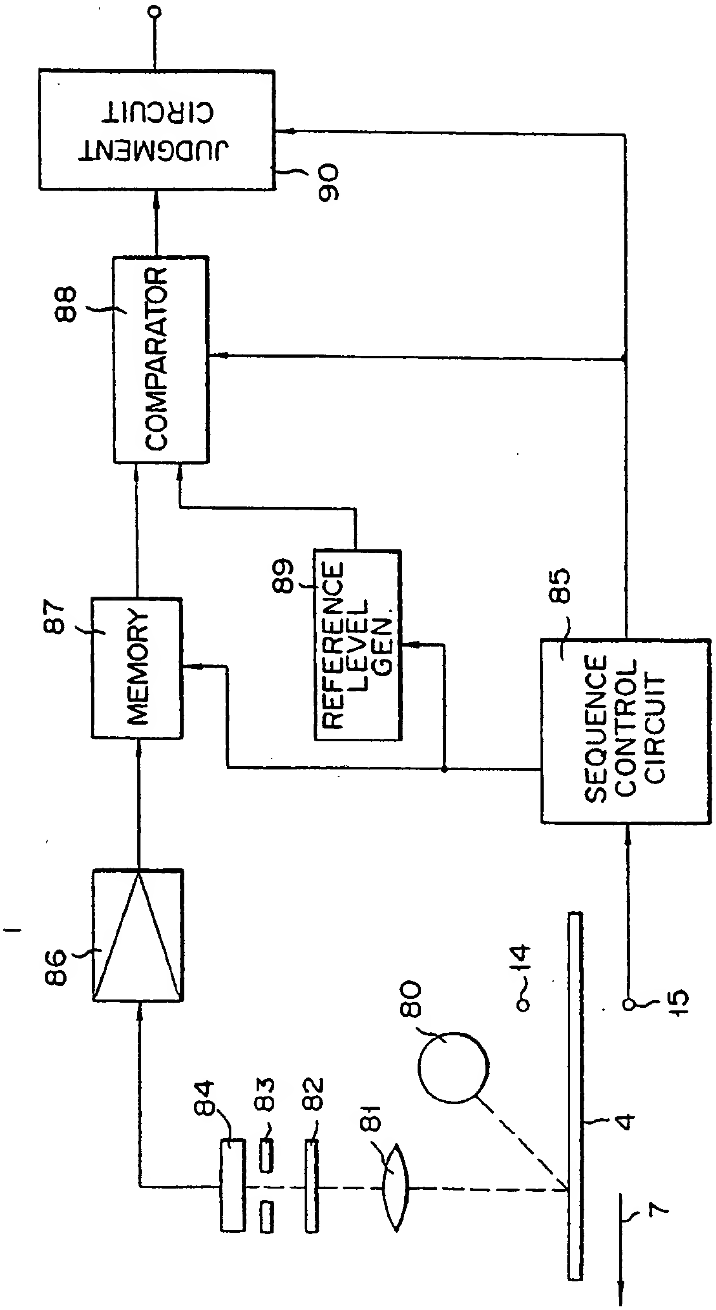

JUDGMENT CIRCUIT
90
COMPARATOR
88
MEMORY
87
REFERENCE LEVEL GEN.
89
SEQUENCE CONTROL CIRCUIT
85
86
84
83
82
81
80
14
15
4
7

FIG. 15

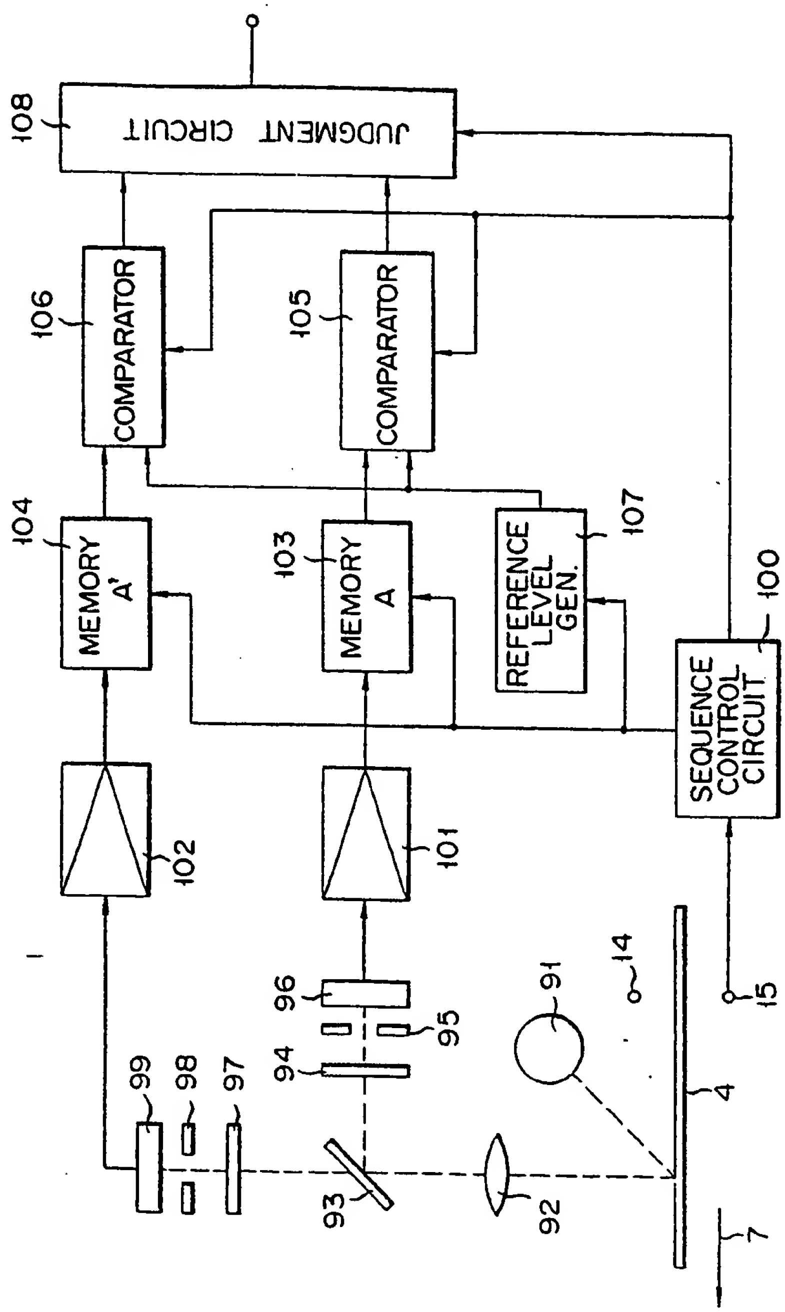

108
JUDGEMENT CIRCUIT
106
COMPARATOR
105
COMPARATOR
104
MEMORY A'
103
MEMORY A
REFERENCE LEVEL GEN.
107
SEQUENCE CONTROL CIRCUIT
100
102
101
99
98
97
96
95
94
93
92
91
14
15
4
7

FIG. 16

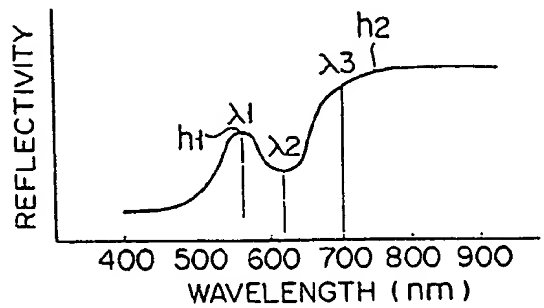


FIG. 17

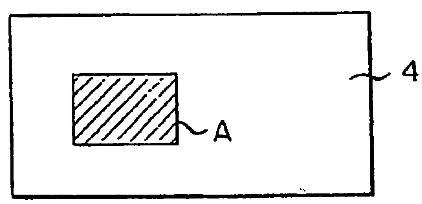
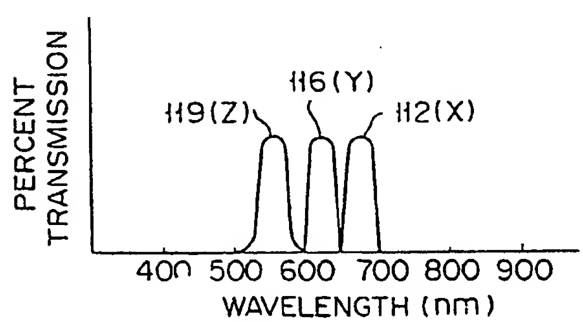
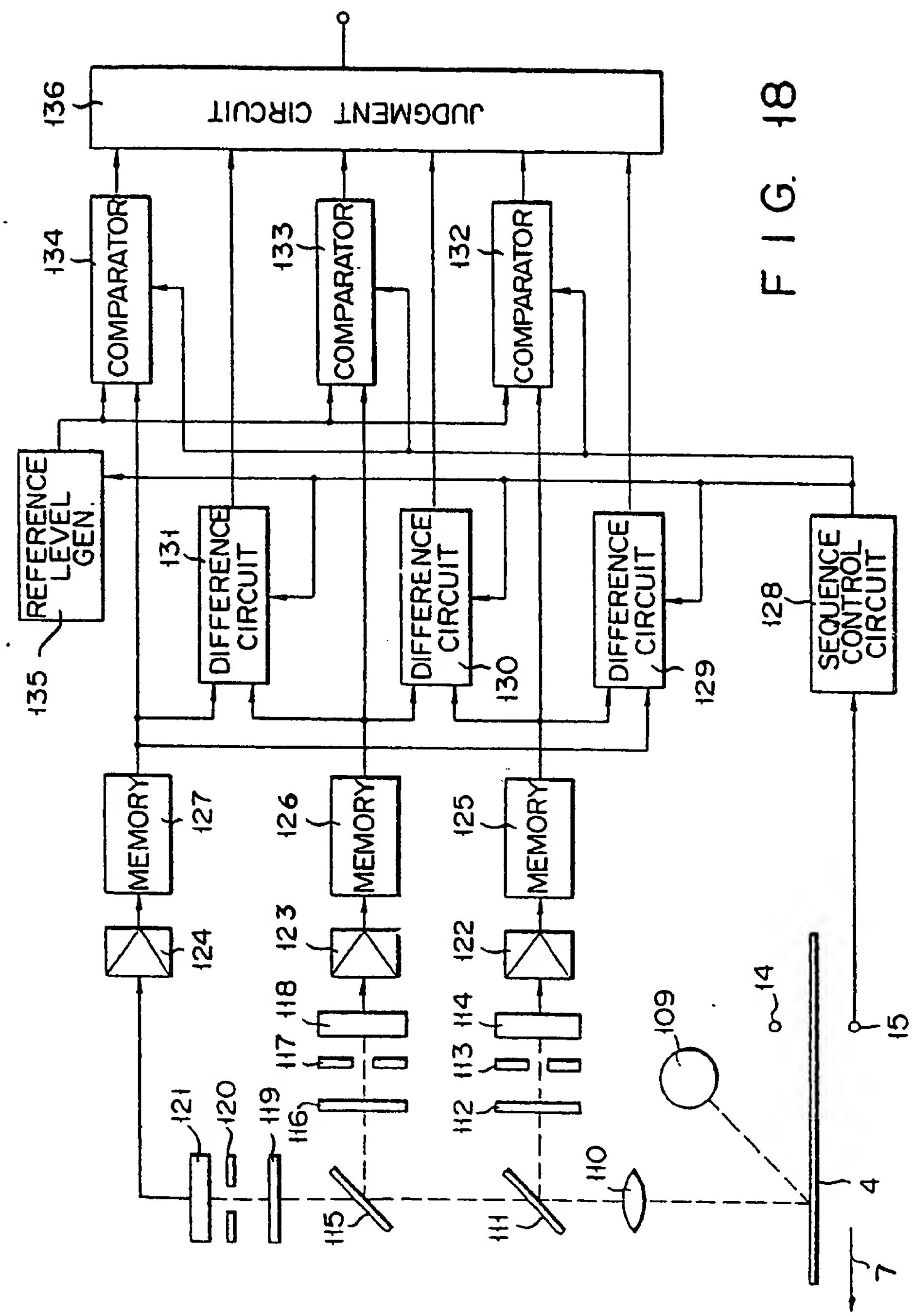


FIG. 19




JUDGMENT CIRCUIT
136
COMPARATOR
134
COMPARATOR
133
COMPARATOR
132
REFERENCE LEVEL GEN.
135
DIFFERENCE CIRCUIT
131
DIFFERENCE CIRCUIT
130
DIFFERENCE CIRCUIT
129
SEQUENCE CONTROL CIRCUIT
128
MEMORY
127
MEMORY
126
MEMORY
125
124
123
122
121
120
119
118
117
116
115
114
113
112
111
110
109
14
15
4
7

F I G. 18

FIG. 20

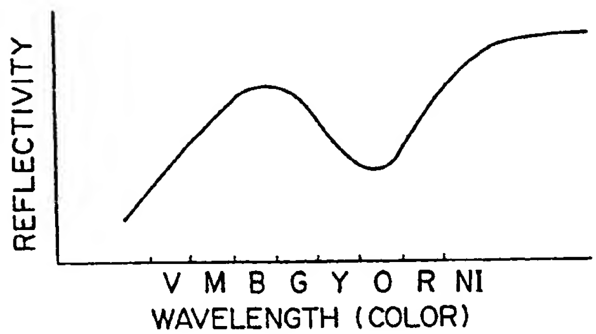
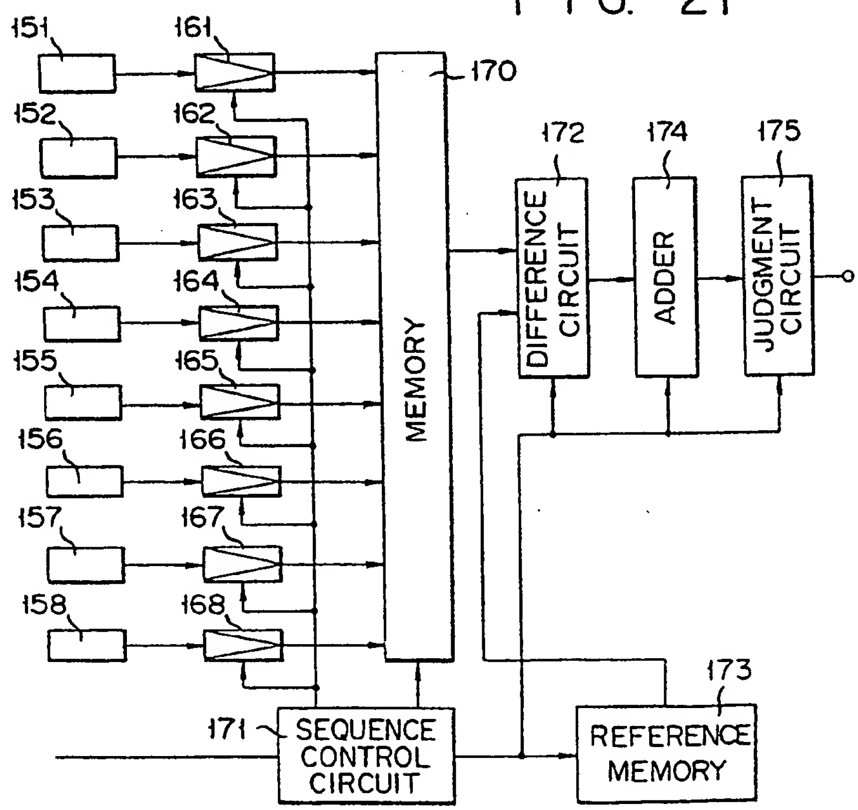

REFLECTIVITY
V M B G Y O R NI
WAVELENGTH (COLOR)

FIG. 21


151
152
153
154
155
156
157
158
161
162
163
164
165
166
167
168
MEMORY
170
172
DIFFERENCE CIRCUIT
174
ADDER
175
JUDGMENT CIRCUIT
173
REFERENCE MEMORY
171
SEQUENCE CONTROL CIRCUIT